(12) UK Patent Application (19) GB (11) 2 191 603 (13) A

(43) Application published 16 Dec 1987

(21) Application No 8713588

(22) Date of filing 10 Jun 1987

(30) Priority data

(31) 511611 (32) 13 Jun 1986 (33) CA

(51) INT CL[4]
G02B 6/12

(52) Domestic classification (Edition I)
G2J GDA GDB

(56) Documents cited
GB A 2181862 US 4472020
GB A 2000877 US 3947087

(58) Field of search
G2J
Selected US specifications from IPC sub-class G02B

(71) Applicant
Northern Telecom Limited,

(Incorporated in Canada-Quebec),

600 de La Gauchetiere Street West, Montreal, Quebec, Canada H3B 4N7

(72) Inventor
Peter Tjing Hak Kwa

(74) Agent and/or Address for Service
A. A. Thornton & Co, Northumberland House, 303-306 High Holborn,
London WC1V 7LE

(54) **Optical conductor having at least three layers**

(57) Optical conductors or waveguides for making interconnections in electronic or photonic equipment may need to follow complex routes. Rigid, rod-like waveguides and individual point-to-point optical fibers are not entirely satisfactory. It is proposed to form optical conductors in the middle layer of a laminar body, for example a three-layer sandwich board 10, by irradiating the board by means of a collimated beam of light 20, for example ultra-violet light. The middle layer 12 of the board is made of a material, for example polycarbonate, which has a refractive index that increases when it is exposed to the light beam. The light beam may be moved relative to the board to trace the required path of the optical conductor which is formed as a higher refractive index channel 22 in the middle layer 12. Monomode or multimode conductors can be produced merely by varying the width of the light beam and the thickness of the middle layer. Alternatively, the laminar body may be exposed through a photomask.

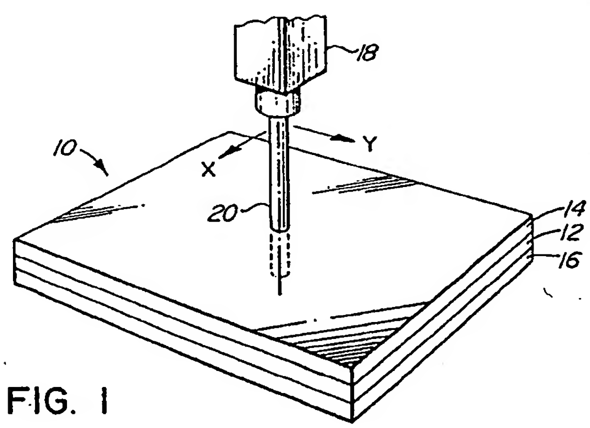

FIG. 1

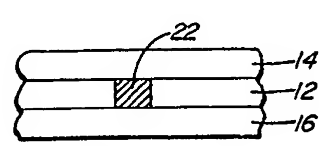

FIG. 2

GB 2 191 603 A

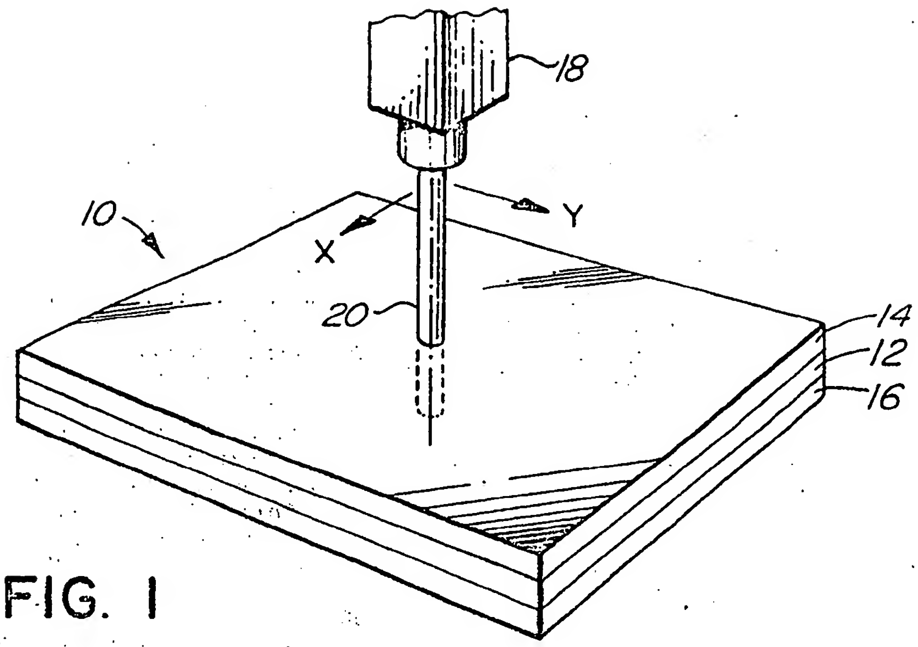

FIG. 1

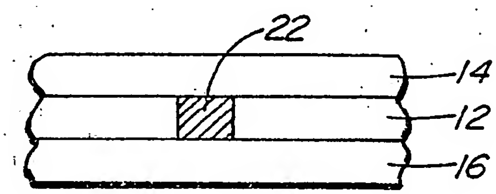

FIG. 2

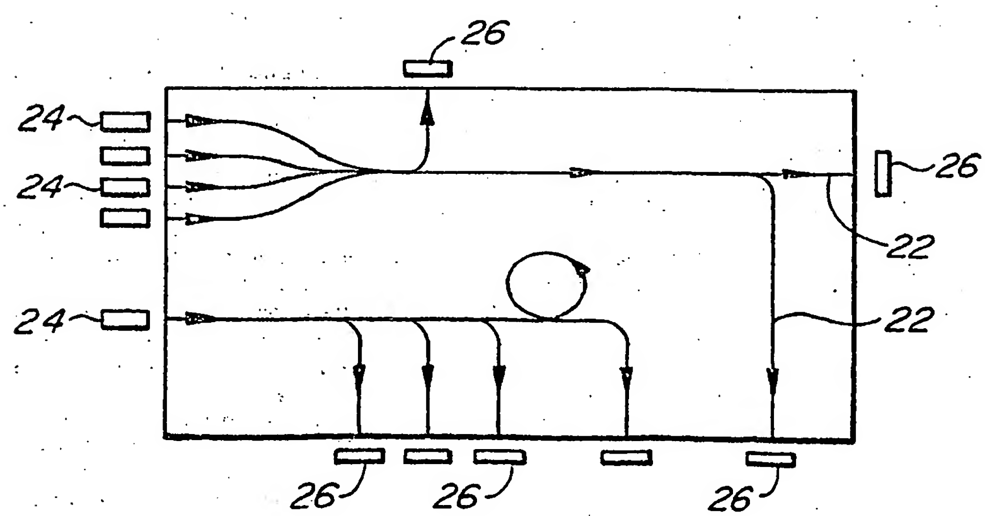

FIG. 3

SPECIFICATION

Optical circuit b ard

Field of the invention

This invention relates to a method of making optical conductor devices for use in making interconnections in electronic and/or photonic equipment.

Background of the invention

Various types of optical conductor have been proposed for making interconnections optically. These include the usual optical fiber comprising a core of 50 μm ϕ, surrounded by a cladding of 125 μm ϕ. The light is confined to the core by virtue of the difference between the respective refractive indices of the core and cladding. Another proposed optical conductor, disclosed in A. Graves' U.S. Patent Application Serial Number 593,682, filed March 26, 1984, comprises a moulding in the form of a rod of optically transmissive material.

These optical conductors are not entirely suitable for making complex interconnections. The optical fibers involve "point-to-point" interconnections and the rigid rods also require coupling pieces.

It has also been proposed to make light guides by "writing" in a block of transparent material the refractive index of which changes upon exposure to a certain radiation. Such a proposal is disclosed in U.S. patent 3,689,264 (Chandross et al) to which the reader is directed for reference.

An object of the present invention is to provide a method of making optical conductors for complex interconnects or "circuits".

Summary of the invention

According to the present invention, a method of making at least one optical conductor in a laminar body, one layer of which has a refractive index that changes when said layer is irradiated by a particular radiation, comprises the step of irradiating by means of a light beam that is collimated at least where it extends within such one layer, so as to form in said layer a channel extending linearly in the plane of said layer and having a refractive index that is higher than that of the adjacent parts of the middle layer and that of the superjacent and subjacent parts, respectively, of the other two layers.

Thus the channel of higher refractive index material is bounded by material having a lower refractive index and so serves as an optical waveguide or conductor. The depth and width of the channel can readily be adjusted, by varying the thickness of the middle layer and the width of the irradiated area, to provide for single-mode or multimode transmission.

The channel of higher refractive index may be formed before or after the middle layer has been sandwiched between th oth rtw . Th form r method can deploy opaque outer layers, protecting the UV-sensitive middle layer. The latter method is practically more convenient because of the use of pre-clad inner layer.

The required change in the refractive index may be achieved by choosing a middle layer having a refractive index that increases when it is irradiated. The channel may then be formed by irradiating only the corresponding parts of the middle layer. Irradiation may be by means of a collimated beam of light which traces the path of the optical conductor(s). The source for the light beam may conveniently be mounted on a numerically-controlled machine. Ultra-violet light may be used to provide a suitable increase in the refractive index of a middle layer composed of polycarbonate.

Alternatively, the layer or sandwich may be covered by a masking layer, analogous to the photomask used in making printed circuit boards, which obscures the areas which are not to be irradiated. The parts to be modified to form the channel are then irradiated through the mask.

It will be appreciated that instead of increasing the refractive index of the channel, the required differential could be achieved by lowering the refractiv index of the areas each side of the channel.

An optical conductor or waveguide formed according to the invention is especially suited to longer wavelength light, especially for infrared and near-infrared.

Brief description of the drawings

An embodiment of the invention will now be d scribed, by way of example only and with referenc to the accompanying drawings, in which:-

Figure 1 is a perspective view of a three-layer sandwich of transparent sheets being irradiated with ultra-violet light from a collimated light source;

Figure 2 is a cross-section through a part of the sandwich after irradiation; and

Figure 3 is a plan view of an optical circuit board made according to the present invention.

Description of a specific embodiment

Referring to Figure 1, a three-layer sandwich 10, comprises a layer 12 of polycarbonate, sandwiched between two layers 14 and 16 of silicon-oxide or acrylic. The refractive index of middle layer 12 can be increased, by exposure to ultra-violet radiation, to a level higher than that of layers 14 and 16, the respective refractive indices of which are not significantly susceptible to ultra-violet radiation.

The sandwich 10 is shown positioned beneath a light source 18 which is mounted on the head of a numerically-controlled machine tool (not shown). The light source 18 directs a collimated beam of ultra-violet light 20 onto and through the sandwich 10. The uppermost layer 14 and lowermost layer 16 are unaffected by the ultra-violet radiation, which passes through them. On the other hand, the refractive index of the middle layer 12 increases where it is irradiated. The light source 18 and sandwich 10 are moved one relative to the other so that the light beam 20 traces a pattern of lines in the sandwich 10. A corr sponding pattern of channels 22, of substantially square cross-section, are formed in the middle layer 12 (see Figures 2 and 3).

As can be seen from the cross-sectional view of Figure 3, each channel 22 is bounded on either side by the unaffected material of its own, middle, layer 12, which was n t irradiated and so has a lower re-

fractive index. It is bounded above and below by the unaffected layers 14 and 16, respectively, which also have a lower refractive index. Consequently the channel 22 constitutes an optical conductor or waveguide which will transmit light along its length.

The above-described method of forming optical conductor boards can be used to form relatively intricate patterns of optical conductors as illustrated in Figure 3. There the optical conductors 22 are shown in conjunction with a set of optical transmitters 24, adjacent the ends of the optical conductors at one edge of the board, and a set of optical receivers 26 disposed at the other ends of the optical conductors 22.

The optical conductors 22 may be adapted for single-mode or multimode transmission simply by adjusting the cross-sectional area of the channel formed in the middle layer, specifically by varying the thickness of the middle layer and the diameter of the collimated beam.

It is envisaged that an optical conductor board made in accordance with the invention will be especially useful for conveying longer wavelength light, especially infrared and near-infrared. The middle layer is UV-sensitive, it would erode quickly if the optical channels within this layer were used to carry short wavelength UV-light. However, this is no restriction at all, since suitable emitters and detectors are well-developed and cheap, e.g. GaAs-emitters and Si-detectors operating at wavelengths of 800nm-900nm.

In this specification, the term "laminar body" is used to embrace a body having superposed layers or laminae. Although the specific embodiment is a three-layer circuit board, the laminar body could be, *inter alia*, a multilayer board, a pair of layers formed directly on a substrate as in thin film, thick film or semiconductor applications, where the substrate, in effect, is another "layer" having a lower refractive index than the optical conductor.

Various modifications are possible within the ambit of the invention. For example, instead of "drawing" the optical conductors using a collimated light beam, the layer could be irradiated through a mask carrying the required pattern of the optical conductors.

Moreover, the middle layer could be irradiated before it is sandwiched between the other two layers. Also, a plurality of three-layer sandwiches might be stacked one on top of the other to form a multilayer optical conductor board.

An advantage of the present invention is that the dimensions of the optical conductor are determined quite definitely because the upper and lower boundaries are formed by the surfaces of the middle layer itself and the sidewalls of the channel are the relatively abrupt transition between irradiated and non-irradiated material. Such an abrupt transition is afforded by the use of a homogenous collimated beam of light. Moreover, the combinati n of laminar body and intersecting light beam allows the r fractive index gradient to be made unif rm across the cross-section of the optical conductor.

CLAIMS

1. A method of making at least one optical conductor in a laminar body one layer of which has a refractive index that changes when such layer is irradiated by a particular radiation, said method comprising the step of irradiating said layer by means of a light beam that is collimated at least where it extends within such one layer so as to form therein a channel extending linearly in the plane of said layer and having a refractive index that is higher than the refractive index of such layer either side of said channel and higher than the refractive indices, respectively, of the layers superjacent and subjacent said channel, the arrangement being such that the cross-sectional dimensions of the channel are determined by the interfaces between said one layer and the superjacent and subjacent layers, respectively, and laterally by the width of the light beam.

2. A method as defined in claim 1, wherein said light beam is passed transversely through said one layer.

3. A method as defined in claim 2, wherein said one layer is irradiated by a collimated light beam from a source, the source and said one layer b ing movable one relative to the other such that said light beam traces the path of said optical conductor.

4. A method as defined in claim 1, 2 or 3, wherein said light source is an ultra-violet light source and said material of said one layer is of polycarbonate.

5. A method as defined in claim 1, 2 or 3 wherein said one layer is irradiated by a collimated light beam from a source, the source and said one layer being movable, one relative to the other, such that said light beam traces the path of said optical conductor, said light source is an ultra-violet light source, and said light beam is homogenous in said layer.

6. A method as defined in claim 1, 2 or 3 wherein the light beam is homogenous in said layer.

7. A method as defined in claim 1, 2 or 3 wherein the superjacent, subjacent and one layer are formed into a laminar body after irradiation of said one layer to form said channel.

8. A method as defined in claim 1, 2 or 3 wherein the superjacent, subjacent, and one layer are formed into a laminar body after irradiation of said one layer to form said channel, said light source is an ultra-violet light source, and said light beam being homogenous in said layer.

9. A method as defined in claim 1 or 2 wherein said one layer is irradiated through a photomask between a light source and said layer to provide said collimated light beam such that said collimated beam is formed by light passing through said photomask.

10. A method of making at least one optical conductor in a laminar body, one layer of which has a refractive index that changes when such layer is irradiated by a particular radiation, said method comprising the step of irradiating said one layer through a photomask so as t f rm a chann l extending linearly in the plane of said layer and having a refractive index that is higher than the refractive indices, respectively, of the layers superjacent and subjacent said channel, the arrangement being such

that the cross-sectional dimensions of the channel are determined by the interfaces between said one layer and the subjacent and superjacent layers, respectively, and laterally by the width of the shadow created by the photomask.

11. An optical conductor device comprising a laminar body having at least three layers, the middle layer having an optical conductor in the form of a channel, extending linearly in the plane of said middle layer and bounded by the interfaces between said middle layer and the superjacent and subjacent layer, respectively, and laterally by a relatively distinct change in the refractive index of such middle layer.

Printed for Her Majesty's Stationery Office by
Croydon Printing Company (UK) Ltd, 10/87, D8991685.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.